Larval Densities and Field Hosts of *Ceratapion basicorne* (Coleoptera: Apionidae) and an Illustrated Key to the Adults of *Ceratapion* spp. That Feed on Thistles in the Eastern Mediterranean and Black Sea Regions

JOE K. BALCIUNAS[1] AND BORIS A. KOROTYAEV[2]

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ABSTRACT Many members of the tribe Cardueae are invasive weeds, including yellow starthistle (*Centaurea solstitialis* L.), one of the most important weeds in the Western United States. We examined the root crowns and stems of yellow starthistle and related plants growing in five countries (Armenia, Republic of Georgia, Greece, Russia, and Turkey) where yellow starthistle is native. In its native range, the root crowns and lower stems of yellow starthistle are frequently attacked by the internal feeding larvae of apionid weevils. We present illustrations and a key to the adults of the six apionid species that we reared from yellow starthistle and its relatives: *Ceratapion basicorne* (Illiger), *C. carduorum* (Kirby), *C. gibbirostre* (Gyllenhal), *C. onopodri* (Kirby), *C. orientale* (Gerstaecker), and *C. penetrans* (Germar). The only apionid we reared from yellow starthistle was *C. basicorne*. In Turkey, where we collected most intensively, 58% of the yellow starthistle at 20 sites had larvae of this weevil, and at sites where *C. basicorne* was present, there were an average of 1.8 immatures per yellow starthistle plant. This apionid is currently being further researched for its potential as a biological control agent for yellow starthistle.

KEY WORDS biological control of weeds, *Centaurea solstitialis*, *Centaurea* species, *Ceratapion* species

The thistle tribe, Cardueae (Asteraceae), includes many invasive weeds, one of which is yellow starthistle *Centaurea solstitialis* L., which is one of the most widespread and damaging weeds in Western United States. Yellow starthistle is recorded from 41 States (USDA PLANTS; Database 2007), with California and the northwestern states the most seriously impacted. In the mid-1950s, this spiny weed, native to the Eastern Mediterranean region, became a target for classical biological control research by USDA–ARS scientists (Balciunas 1998). This effort is still ongoing and has resulted in six insect species from Greece and Italy, being approved for release in the United States. Five of these, three weevils and two tephritid flies from Greece, became established, and are now frequently found attacking flowers and developing seeds of yellow starthistle in the Western United States (Pitcairn et al. 1998, 2000). In addition, another fly from Greece, *Chaetorellia succinea* Costa (Diptera: Tephritidae), was unintentionally released in 1991, and has now become widespread on yellow starthistle, especially in California (Balciunas and Villegas 1999).

Unfortunately, yellow starthistle continues to spread, and additional agents are needed, especially those attacking yellow starthistle before it flowers (Balciunas 1998, Bruckart and Eskandari 2002, Smith 2002). Therefore, in 1996, the first author visited Greece and Turkey to search for additional biological control agents for yellow starthistle. He examined preflowering starthistle plants at more than three dozen sites in these two countries. Although he occasionally found some insects feeding externally on rosettes and newly bolted yellow starthistle, at most sites, a large portion of these younger plants had internal damage caused by apionid larvae tunneling in the root crown and lower portions of yellow starthistle stems. This was thought to be caused by the larvae of *Ceratapion basicorne* (Illiger), the apionid previously reared from yellow starthistle in Greece, Italy (Clement 1990), and Turkey (Rosenthal et al. 1994). Currently, apionid larvae cannot be identified to species, so we reared them to the adult stage. In 2001, the co-author visited United States, examined all the apionids reared by first author, and identified them.

Identifying the adults of *Ceratapion* spp. requires access to, and familiarity with, two monographs that are not readily available to most entomologists (Alonso-Zarazaga 1990 and Wanat 1995). To assist future researchers, we have prepared original figures and include a key to adult weevils.

[1] Corresponding author: Exotic and Invasive Weed Research Unit, USDA–ARS, Western Regional Research Center, 800 Buchanan Street, Albany, CA 94710 (e-mail: joe@pw.usda.gov).

[2] Zoological Institute, Russian Academy of Sciences, St. Petersburg 199034, Russia.

Materials and Methods

The results reported in this article are from the research conducted during three extended field trips to the eastern Mediterranean and Caucasus mountain regions. The first was in 1996, when the first author visited Greece and Turkey. The second was in 1997, when he visited the Republic of Georgia, Turkey, and Greece. In 1999, after brief visits to Greece, Turkey, and Armenia, he was joined by the co-author in Krasnodar Territory in southern Russia. All three trips were in May and June, before the yellow starthistle in these regions came into full bloom.

Rearing, Field Hosts, and Identification. After arriving at a field site, we would confirm the presence of apionids by uprooting yellow starthistle plants out of the ground and splitting the stems and root crowns of at least 15 plants with a knife. If apionid larvae/pupae were found, additional yellow starthistle plants (usually ≈20) and plant species related to yellow starthistle were collected. The stems were cut off ≈5–10 cm above the root crown, and the root crowns with attached stem-stubs of each plant species from a site were placed in a labeled Zip-lock bag (31 by 32 cm) that had a 15 by 10 cm nylon mesh-covered ventilation hole on one side. The bag was examined daily for *Ceratapion* emergence, and every few days, excess moisture on the root crowns and inside the bags was removed by blotting with paper towels.

All emergence bags were transported to the USDA–ARS European Biological Control Laboratory's (EBCL) Thessaloniki Field Station in northern Greece. The adult *Ceratapion* that emerged were mounted, labeled, and shipped back to the United States. The co-author examined and identified all these reared apionids, relying primarily on descriptions and keys of Alonso-Zarazaga (1990) and Wanat (1995). Representative samples were taken to St. Petersburg and compared with identified specimens in the Zoological Institute, Russian Academy of Sciences. A professional scientific illustrator, N. A. Florenskaya (St. Petersburg), was contracted to illustrate the six *Ceratapion* spp. we reared. Most of these specimens are retained in our collection at Albany, CA, and voucher specimens have been deposited at the USDA–ARS Systematic Entomology Laboratory to be incorporated into the United States National Museum (USNM), in Washington, DC.

Infestation Rates by *C. basicorne*. On 27 May 1996, near the village of Gamali in northern Greece, the first author, with the assistance of the EBCL staff, conducted a field survey to measure attack rates on this population of yellow starthistle and to determine which plant portion and phenological stage of yellow starthistle were preferred by *C. basicorne.* The site, along the margins of a farm road and adjacent to a wheat field, was heavily infested by yellow starthistle in various stages of growth. We randomly collected ≈100 yellow starthistle plants by pulling them out of the ground and measured each plant's height (above the root crown) and the maximum diameter of the root crown. Each plant was classified as being one of three growth stages: (1) seedling stage, a prerosette, that had not yet developed the lateral rosette leaves; (2) rosette stage, rosette leaves present but plants lacking inflorescences; (3) bud stage, larger plants that had bolted and had developed inflorescences. On this day, none of these plants had yet fully flowered, and the heads were in the Bu1 to Bu3 stages using the Maddox (1981) classification scheme for yellow starthistle head development. We split the stems and root crowns and recorded the number of apionid larvae and empty larval tunnels in each plant portion.

During 1997 and, to a lesser degree 1999, we collected data on regional variations in *C. basicorne* infestation rates. To allow visiting several sites each day, an abbreviated version of the above protocol was used. At each site, the latitude and longitude was noted from a GPS unit (except when the batteries failed), the plant height range was recorded, and the modal height estimated. Usually, 10–20 plants were uprooted (up to 40, if apionid infestation rates were low) and split, and the number with apionid larvae, pupae, and/or damage recorded. If yellow starthistle plants were rare at the site, all the plants were collected and examined. Sometimes only a single plant could be found. These destructive samples did not allow rearing to confirm the identity of the larvae in the yellow starthistle root crowns, because the undamaged larvae leave the split plants and perish. Because in previous years we had only reared *C. basicorne* from yellow starthistle and because no other *Ceratapion* spp. have been recorded to have yellow starthistle as a larval host in this region (Wanat 1995), we feel that any apionid larva found in yellow starthistle root crowns and lower stems is almost certainly *C. basicorne.*

We statistically analyzed our data using a standard software package (Statistix 2005).

Results and Discussion

Identification. The adult weevils that we reared from the root crowns and lower stems of yellow starthistle and 10 other plant species in the tribe Cardueae were members of the genus *Ceratapion* and belonged to six different species. The adults can be separated using the key presented in *Appendix 1.* Body length was measured from anterior margin of eye to the apex of elytra, when viewed dorsally. The range of body lengths cited for each species is from Wanat (1995).

Field Hosts. During 1997 and 1999, we successfully reared nearly 200 specimens of apionid adults from infested root crowns and lower stems of yellow starthistle and 10 other plant species in the Tribe Cardueae (Table 1). Because we did not usually sample additional host plants unless we first found apionid larvae in yellow starthistle, this plant comprised nearly one half of our collections. The only apionid we reared from the yellow starthistle samples was *C. basicorne.* Therefore, during 1999, we assumed that all larvae inside yellow starthistle root crowns were *C. basicorne*

Table 1. Number of adults of *Ceratapion* spp. weevils (Coleoptera: Apionidae) reared from various thistle host plant species (Asteraceae: Tribe Carduae) growing in the eastern Mediterranean and Black Sea regions of Eurasia

	Carduus pycnocephalus L. Greece (3 sites)	*Centaurea benedicta* (L.) L. Turkey (1 site)	*Centaurea cyanus* L. Turkey (3 sites)	*Centaurea diffusa* Lamarck Greece (1 site)	*Centaurea solstitialis* L. Georgia (3 sites)	*Centaurea solstitialis* L. Turkey (8 sites)	*Centaurea* sp. Russia (1 site)	*Cirsium* sp. Greece (1 site)	*Crupina vulgaris* Cassini Greece (1 site)	*Cynara cardunculus* L. Greece (1 site)	*Galactites tomentosa* Moench Georgia (1 site)	*Silybum marianum* (L.) Gaertner Georgia (2 sites)
Ceratapion basicorne (Illiger)		4	29		29	60						
Ceratapion carduorum (Kirby)										2		
Ceratapion gibbirostre (Gyllenhal)	25											6
Ceratapion onopordi (Kirby)								4			1	
Ceratapion orientale (Gerstaecker)		5							12			
Ceratapion penetrans (Germar)				1			4					

and concentrated on measuring geographic variation in larval densities and rearing larvae collected from other hosts. We also reared *C. basicorne* from three samples of *Centaurea cyanus* L. (bachelor's button, cornflower) and from one sample of blessed thistle, *Centaurea benedicta* (L.) L. (formerly *Cnicus benedictus* L.; Table 1). Although both yellow starthistle and *Cnt. cyanus* were previously known as hosts for larvae of *C. basicorne* (Alonso-Zarazaga 1990, Wanat 1995), blessed thistle is a new larval host record for this apionid. Smith (2007) has confirmed that both *Cnt. cyanus* and blessed thistle will, under laboratory conditions, support oviposition and development of *C. basicorne.* Rosenthal et al. (1994) also report squarrose knapweed, *Centaurea squarrosa* Willdenow, as a rare host for this apionid in Turkey.

The next most numerous apionid species was *C. gibbirostre* (Gyllenhal), which we reared from three samples of Italian thistle, *Carduus pycnocephalus* L., from Greece and two samples of milk thistle, *Silybum marianum* (L.) Gaertner, from the Republic of Georgia. The former is a known larval host for this apionid (Wanat 1995), but the latter is a new host record. Compared with *C. basicorne, C. gibbirostre* has a larger known host range. Alonso-Zarazaga (1990) and Wanat (1994) report *Carduus acanthoides* L., *Crd. nutans* L., *Crd. tenuiflorus* Curtis, *Cirsium arvense* L. (Scopoli), and *Cir. eriophorum* L. (Scopoli) as larval hosts.

We reared 17 adults of *C. orientale* (Gerstaecker) from a Turkish sample of blessed thistle and a Greek sample of common crupina, *Crupina vulgaris* Cassini. A review of the specimens at the Zoological Institute, St. Petersburg showed that in Krasnodar and Stavropol territories and Republic of Adygea in the Northwestern Caucasus, Russia, this weevil is common only on *Centaurea diffusa* Lamarck. The only host known previously for this apionid was *Centaurea rhenana* Borbas (Wanat 1995).

Because we were able to rear, at most, only a handful of each of *C. carduorum* (Kirby), *C. onopordi* (Kirby), and *C. penetrans* (Germar), it would be inappropriate to make strong statements about what plants are their preferred hosts. We also dissected plants of eight additional thistle tribe species (*Carduus nutans* L., *Carthamus lanatus* L., *Centaurea calcitrapa* L., *Cirsium acarna* (L.) Moench, *Cir. arvense* (L.) Scopoli, *Onopordum acanthium* L., *O. illyricum* L., and *O. tauricum* Willdenow) in which we did not detect any apionids or their damage. We did not rear any of the six *Ceratapion* spp. that we found from more than two host plants species, and only one plant species (*Centaurea benedictus*) was a host for multiple *Ceratapion* spp.

Distribution and Infestation Rates of *C. basicorne*. Knowledge of a potential biological control agent's density and its regional variation can assist in predicting impact and spread after release in the United States. We dissected 252 yellow starthistle plants from 20 yellow starthistle sites in Turkey (Table 2). Sixteen sites had *C. basicorne* present, and at these sites, 65% of the plants were infested by *C. basicorne* at mean infestation rate of 1.8 immatures per plant. Uygur et al. (2004) report that 25–100% of the yellow starthistle rosettes in central Turkey are attacked by this apionid. Our four Turkish sites without *C. basicorne* were all near Turkey's southern coast, and yellow starthistle was uncommon at those sites. Uygur (2004) reported that *C. basicorne* was present at 18.4% of her yellow starthistle sites in southern Turkey and that the average infestation rate was 59%. In Greece, 6 of the 13 yellow starthistle sites we examined during 1997 had *C. basicorne,* and of the 254 plants examined, only 21% were infested, but the 7 sites with *C. basicorne* had a mean infestation rate of 0.6 immatures per plant. As in Turkey, coastal yellow starthistle sites usually did not have *C. basicorne.*

During our 1999 field trip to Armenia, yellow starthistle was not often found. However, *C. basicorne* was present at both sites in Armenia where we found yellow starthistle and infested 29% of the 17 plants examined at mean rate of 1.0 larvae per plant. This weed was more common in the Black Sea coastal regions of Krasnodar Territory of southern Russia. A total of 60 plants were examined at three yellow

Table 2. Number of *Ceratapion basicorne* immatures found in root crowns and lower stems of yellow starthistle at field sites in Asia and Europe during 1997 and 1999

Collection number	Country	Date	Latitude	Longitude	Elevation (m)	Site	Yellow starthistle plants examined	Plants infested with *C. basicorne*	*C. basicorne* larvae, pupae, or damage
99ARM03	Armenia	5/27/99	39°57.15′ N	44°52.32′ E	1,130	Just inside Khosrov Nature Reserve near Vedi	15	6	10
99ARM04	Armenia	5/27/99	39°41.05′ N	45°14.04′ E	1,450	Noravank church	2	1	2
97GRC01	Greece	5/27/97	37°46.37′ N	22°39.63′ E	450	North of Tripoli on rd from Corinth to Tripoli	18	0	0
97GRC02	Greece	5/27/97	37°30.22′ N	22°24.22′ E	740	0.5 km E int. Argos-Trip. & Nafplio-Trip. hyw	23	0	0
97GRC03	Greece	5/28/97	37°05.40′ N	22°22.76′ E	400	10 km N of Sparti on rd to Kalamata	25	2	2
97GRC04	Greece	5/28/97	36°59.92′ N	21°51.28′ E	360	0.5 km S of village of Kazarma	29	0	0
97GRC05	Greece	5/28/97	37°04.96′ N	21°37.08′ E	175	About 1 km past Flola	24	0	0
97GRC07	Greece	5/28/97	38°22.28′ N	22°06.25′ E	100	3 km S of Gravia on rd to Amfissa	8	0	0
97GRC08	Greece	5/28/97	38°39.50′ N	22°25.52′ E	560	35 km N of Amfissa on rd to Lamia	16	4	4
97GRC09	Greece	5/29/97	39°03.76′ N	22°53.35′ E	60	270 km mark on Athens/Thessaloniki rd	12	1	1
97GRC10	Greece	6/2/97	40°46.34′ N	21°51.82′ E	560	67 km E of Florina, at rd to Arnissa	21	7	10
97GRC12	Greece	6/3/97	40°48.73′ N	21°31.80′ E	690	13 km E of Florina on rd to Kozani	18	9	11
97GRC13	Greece	6/3/97	40°27.62′ N	21°45.20′ E	680	5 km S of Ptolemaida on rd to Kozani	10	10	35
97GRC14	Greece	6/3/97	40°22.17′ N	21°52.51′ E	700	7 km NE of Kozani at rd to Galani	10	0	0
99GRC01	Greece	5/11/99	?	?		Komotini (8 mi E) towards Alexandropoulos	40	21	21
99KRS01	Russia	5/31/99	45°16.59′ N	37°23.51′ E	45	Temryuk	20	15	27
99KRS02	Russia	6/1/99	45°40.56′ N	36°50.53′ E		Taman	20	4	8
99KRS03	Russia	6/1/99	44°56.78′ N	37°19.29′ E		Anapa railway station	20	1	2
97ESP01	Spain	6/8/97	?	?	?	N2 hwy at rd to Gelsa	15	2	2
97ESP01	Spain	6/8/97	?	?	?	7 km E of Mediara	10	3	3
97Tur04	Turkey	5/18/97	37°52.44′ N	30°47.08′ E	1,070	23.3 km NE of Isparta	10	10	17
97Tur10	Turkey	5/20/97	39°07.40′ N	31°11.60′ E	960	70 km NE of Afyon on rd to Ankara	18	3	10
97Tur11	Turkey	5/20/97	38°47.95′ N	31°44.39′ E	980	200 m N of Yanuk city border	15	12	21
97Tur12	Turkey	5/21/97	38°35.43′ N	31°03.69′ E	920	2 km E of Ç on rd to Konya	10	10	30
97Tur13	Turkey	5/21/97	38°17.22′ N	31°31.76′ E	1,110	1 km E of Üçüyuic village	25	12	12
97Tur14	Turkey	5/21/97	38°08.43′ N	31°43.67′ E	1,140	5 km (?) E of Doğanhisar	6	6	22
97Tur15	Turkey	5/21/97	37°58.31′ N	31°55.42′ E	1,250	A few km further SE of site 97Tur15	17	17	70
97Tur16	Turkey	5/21/97	38°00.38′ N	31°55.18′ E	1,480	1 km W of Derbert turnoff	2	0	0
97Tur18	Turkey	5/22/97	37°45.81′ N	32°55.79′ E	930	2.4 km S of Yarma on rd to Çumra	15	13	40
97Tur19	Turkey	5/23/97	38°10.01′ N	32°44.15′ E	1,000	35 km ? N of Konya on rd to Ankara	14	14	70
97Tur20	Turkey	5/23/97	39°07.70′ N	33°05.85′ E	960	2–3 km N of Kulu on rd from Konya	11	7	10
97Tur21	Turkey	5/23/97	39°05.40′ N	33°25.07′ E	935	3 km NE of Tuz Gölü on D757 to Kirşehir	12	12	30
97Tur22	Turkey	5/24/97	?	?	1,000	50 m E of Kirşehir city limits	10	5	8
97Tur24	Turkey	5/24/97	38°56.25′ N	34°59.76′ E	1,206	2 km S of Kalaba on rd to Nevşehir	15	14	27
97Tur25	Turkey	5/24/97	38°37.74′ N	34°46.09′ E	1,160	Just W of Uçhisar, 10 km E of Nevşehir	11	8	24
97Tur26	Turkey	5/25/97	37°38.97′ N	34°32.04′ E	1,490	About 20 km N of Ulukişla	15	2	2
97Tur27	Turkey	5/26/97	?	?	350?	Tarsus	15	0	0
97Tur28	Turkey	5/26/97	?	?	?	5–10 km N of 97Tur27 on rd to Pozanti	10	0	0
97Tur29	Turkey	5/26/97	?	?	1,200?	Pozanti research station	1	0	0
99Tur01	Turkey	5/17/99	?	?	70	10 km W of Tarsus	20	1	1

starthistle sites there, and *C. basicorne* was present at all three sites and infested 33% of the plants examined. A single large population of yellow starthistle in the continental part of Krasnodar Territory, at its eastern border on the right bank of the Kuban River, briefly examined by the co-author in May 2004, seemed to be uninfested by *Ceratapion.* The easternmost records of this species in the collection of the Zoological Institute, St. Petersburg, are those from Pskov, Yaroslavl, and Lipetsk provinces of Russia, Ukraine (Kiev and

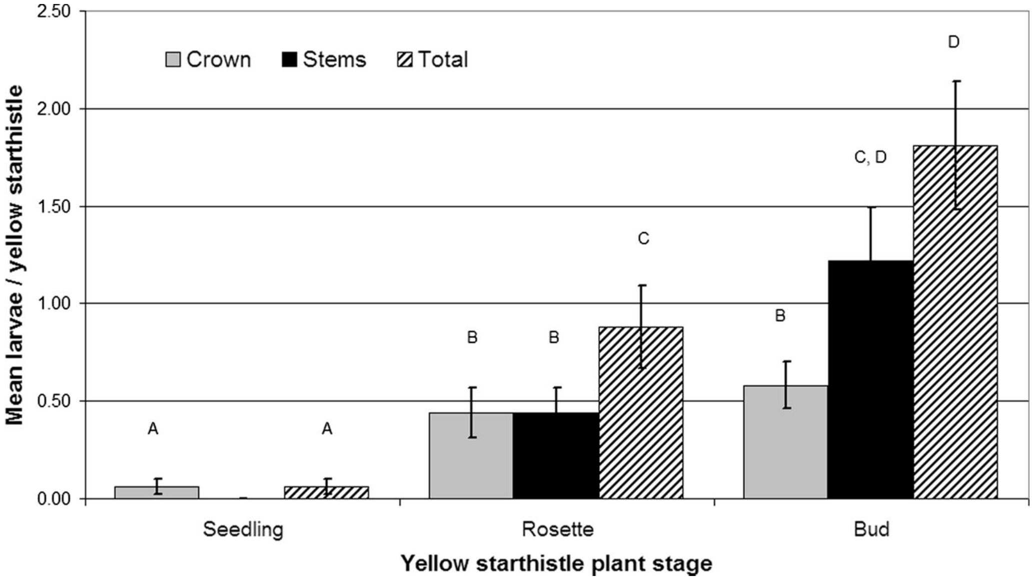

Fig. 1. Mean number (±SE) of *Ceratapion basicorne* larvae found in root crowns and stems of three stages [seedling, rosette, and budding] of yellow starthistle plants growing near Gamali, Greece. Bars with the same letter are not significantly different ($\alpha = 0.05$).

Poltava Provinces, the Crimea), Northwestern Krasnodar Territory (Taman Peninsula). The Zoological Institute also has specimens of *C. basicorne* from Eastern Caucasus (Daghestan, Georgia, and Azerbaijan). Because yellow starthistle is known only from the Crimea and Krasnodar Territories, in other parts of the former USSR and the Ukraine, *C. basicorne* probably has other hosts.

Ceratapion penetrans, the apionid most closely resembling *C. basicorne,* apparently is distributed further eastward; it has been collected in Russia: the lower Volga area (Volgograd Province), and southern Urals (Orenburg Province); and in Western and Central Kazakstan. During seven collecting trips to eastern and central parts of Turkey by the coauthor, no specimens of *C. penetrans* were found on any of the numerous *Centaurea* and other asteraceous species that he examined. In Krasnodar Territory, he commonly found *C. penetrans* on *Centaurea salicifolia* Bieberstein ex. Willdenow, and it often co-occurs on this plant with *Larinus obtusus* Gyllenhal (Coleoptera: Curculionidae). These two species are present together in a few recent collections from Volgograd Province, but no data on their hosts there are available. A series of *C. penetrans* was taken by coauthor from *Cnt. diffusa* on the Sea of Azov shore on the Taman Peninsula.

Although yellow starthistle is not common in Spain, during a 1997 drive from Barcelona to Madrid, the first author collected 25 yellow starthistle plants at two sites, of which 25% were infested. These larvae were not reared, but we believe that it is likely that they were *C. basicorne,* which has been recorded from this region of Spain (Alonso-Zarazaga 1990).

Within most countries where we found *C. basicorne,* variation in infestation rates was great between sites, ranging from 0 to 100% of the plants, including many with multiple larvae. The phenological stage of yellow starthistle plants has an important role in how many *C. basicorne* larvae will be detected when a plant is dissected. In our intensive study of *C. basicorne* infestation rates at a field near Gamali, Greece (Fig. 1), we found that the 33 small, seedling plants, averaging 13.3 ± 0.97 cm in height and with a mean crown width of 0.22 ± 0.02 cm, were very unlikely to have *C. basicorne* larvae (only two larvae were found in 33 plants). In the 36 medium-sized, rosette plants (24.2 ± 1.2 cm high, 0.54 ± 0.04 cm crown width), there were 32 larvae in 15 of the plants, although 21 had none. The 36 most mature plants, those having buds and averaging 76.4 ± 2.9 cm high (1.45 ± 0.07 cm crown), had an average of 1.81 ± 0.3 larvae in each plant, with only eight being uninfested. Although the average number of larvae in the root crowns of medium rosettes (mean = 0.44 ± 0.13) was not significantly different from the older, budding plants (Mann-Whitney rank sum $t = 1230$, $P = 0.349$), the difference between the numbers of larvae in the lower stems was highly significant ($t = 1106$, $P = 0.019$). Thus, the additional larvae in older plants appear to be in the stems.

Prospects of *C. basicorne* as a Biological Control Agent. Our studies confirmed that *C. basicorne* is the most prevalent organism damaging the root crowns and lower stems of yellow starthistle in the Mediterranean region (Clement 1990, Rosenthal et al. 1994). In the field, *C. basicorne* prefers yellow starthistle and bachelor button as larval hosts, although it may occasionally be reared from blessed thistle and squarrose knapweed. This widespread apionid was considered as a candidate biological control agent for yellow starthistle, but ruled out because of concern it might damage safflower (Clement et al. 1989). However, Balciunas (1998) considered that the results of Clement et al. (1989) were not completely conclusive and urged more field and laboratory tests for this apionid. Recent field tests in Turkey, including placing safflower "trap plants" among yellow starthistle heavily infested with *C. basicorne,* have confirmed that this apionid has a very narrow host range in the field (Uygur et al. 2005, Smith et al. 2006, Smith 2007). Quarantine evaluations of this weevil's host range are complete and show a narrow host range (Smith 2007). Therefore, release of *C. basicorne* in the United States has been requested (L. Smith, personal communication).

Earlier versions of our illustrations and key assisted in these host range studies of *C. basicorne.* Also, because almost all of the thistle hosts that we sampled are significant weeds in the United States, some of these other *Ceratapion* spp. could be considered as biological control agents for some of these weeds. For example, the narrow known host range of *C. orientale* should allow it to be considered as a potential biological control agent for blessed thistle.

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References Cited

Alonso-Zarazaga, M. A. 1990. Revision of the subgenera *Ceratapion* s. str. and *Echinostroma* nov. of the genus *Ceratapion* Schilsky, 1901 (Coleoptera, Apionidae). Fragmenta Entomol. 22: 399–528.

Balciunas, J. 1998. The future of biological control for yellow starthistle, pp. 93–95. *In* M. S. Hoddle (ed.), Proceedings California Conference on Biological Control: Innovations in Biological Control Research, 10–11 June 1998, University of California, Berkeley, CA.

Balciunas, J., and B. Villegas. 1999. Two new seed head flies attack yellow starthistle. Calif. Agric. 53: 8–11.

Bruckart, W. L., and F. Eskandari. 2002. Factors affecting germination of *Puccinia jaceae var. solstitialis* teliospores from yellow starthistle. Phytopathology 92: 355–360.

Clement, S. L. 1990. Insect natural enemies of yellow starthistle in southern Europe and the selection of candidate biological control agents. Environ. Entomol. 19: 1882–1888.

Clement, S. L., M. A. Alonso-Zarazaga, T. Mimmochi, and M. Cristofaro. 1989. Life history and host range of *Ceratapion basicorne* (Coleoptera: Apionidae) with notes on other weevil associates (Apionidae) of yellow starthistle in Italy and Greece. Ann. Entomol. Soc. Am. 82: 741–747.

Maddox, D.M. 1981. Introduction, phenology, and density of yellow starthistle in coastal, intercoastal, and Central Valley situations in California. Agricultural Research Results, USDA–ARS, Oakland, CA.

Pitcairn, M. J., D. B. Joley, and D. M. Woods. 1998. Impact of introduced insects for biological control of yellow starthistle, pp. 88–92. *In* M. S. Hoddle (ed.), Proceedings, California Conference on Biological Control: Innovations in Biological Control Research, 10–11 June 1998, University of California, Berkeley, CA.

Pitcairn, M. J., D. M. Woods, D. B. Joley, C. E. Turner, and J. K. Balciunas. 2000. Population buildup and combined impact of introduced insects on yellow starthistle (*Centaurea solstitialis* L.) in California, pp. 747–751. *In* N. R. Spencer (ed.), Proceedings of the X International Symposium on Biological Control of Weeds, 5–9 July, 1999, Montana State University, Bozeman, MT.

Rosenthal, S. S., T. Davarci, A. Ercis, B. Platts, and S. Tait. 1994. Turkish herbivores and pathogens associated with some knapweeds (Asteraceae: *Centaurea* and *Acroptilon*) that are weeds in the United States. Proc. Entomol. Soc. Wash. 96: 162–175.

Smith, L. 2002. New developments in the biological control of invasive weeds. Proc. Calif. Weed Soc. 54: 159–165.

Smith, L. 2007. Physiological host range of *Ceratapion basicorne,* a prospective biological control agent of *Centaurea solstitialis* (Asteraceae). Biol. Control 41: 120–133.

Smith, L., R. Hayat, M. Cristofaro, C. Tronci, G. Tozlu, and F. Lecce. 2006. Assessment of risk to safflower by *Ceratapion basicorne* (Coleoptera: Apionidae), a prospective biological control agent of *Centaurea solstitialis* (Asteraceae). Biol. Control 36: 337–344.

Statistix 8.1. 2005. Computer software. Statistix, Tallahassee, FL.

USDA Natural Resources Conservation Service. 2007. PLANTS National Database, Version 3.5. National Plant Data Center, Baton Rouge, LA.

Uygur, S. 2004. Density of *Centaurea solstitialis* L. and its natural enemies *Ceratapion* spp. in Southern Turkey. Turk. J. Agric. For. 28: 333–339.

Uygur, S., L. Smith, F. N. Uygur, M. Cristofaro, J. Balciunas. 2005. Field assessment in the land of origin of host specificity, infestation rate and impact of *Ceratapion basicorne* a prospective biological control agent of yellow starthistle. Biocontrol 50: 525–541.

Wanat, M. 1995. Systematics and phylogeny of the tribe *Ceratapiini* (Coleoptera: Curculionidae: Apionidae). Int. J. Invertebr. Taxon. Suppl., pp. 1–406.

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Appendix 1

Key to species of *Ceratapion* weevils reared from *Centaurea solstitialis* and other Cardueae thistles in the Eastern Mediterranean and Black Sea regions.

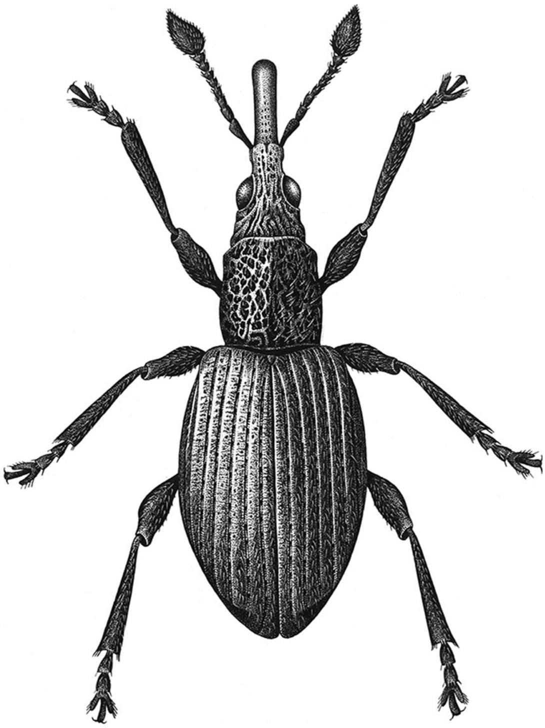

Fig. 2. *Ceratapion onopordi* (Kirby) ♀, dorsal view.

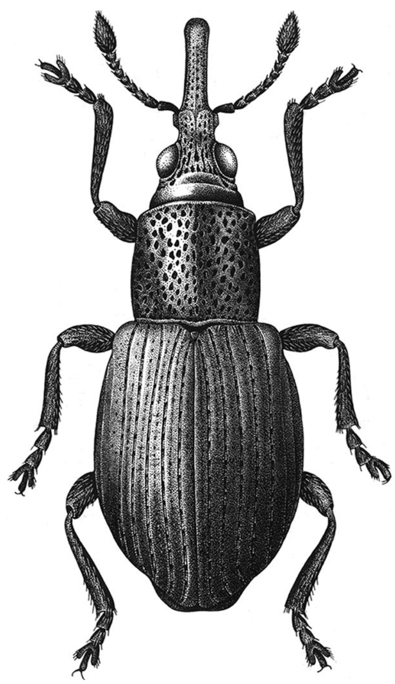

Fig. 3. *Ceratapion orientale* (Gerstaecker) ♀, dorsal view.

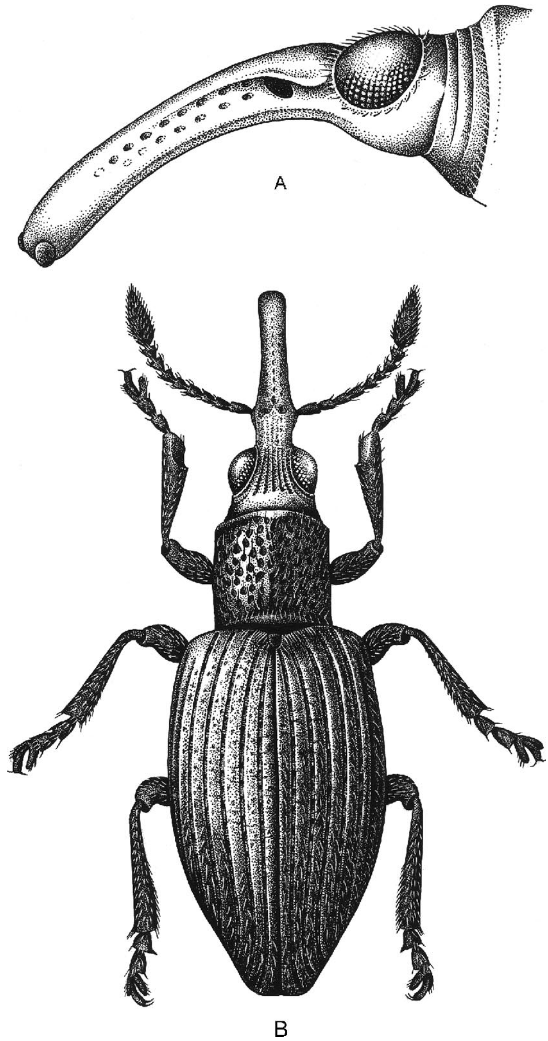

Fig. 4. *Ceratapion basicorne* (Illiger). (**A**) ♀ head, side view. (**B**) ♂, dorsal view.

1a. Rostrum almost straight, not or slightly longer than head capsule and pronotum combined. Frons flattened. Elytra relatively short, with distinct metallic blue-green sheen. Male fore tibia straight, neither flattened nor conspicuously dilated apically, without spine near apex on inner margin. First segment of male hind tarsus without denticle near apex ventrally.- - - - - - - - - - - - -(3)

1b. Rostrum moderately to strongly curved, slightly to considerably longer than head capsule and pronotum combined. Frons flat, weakly convex, or shallowly depressed. Elytra usually more elongate, matte, often with blue-green tint scarcely distinguishable. Male fore

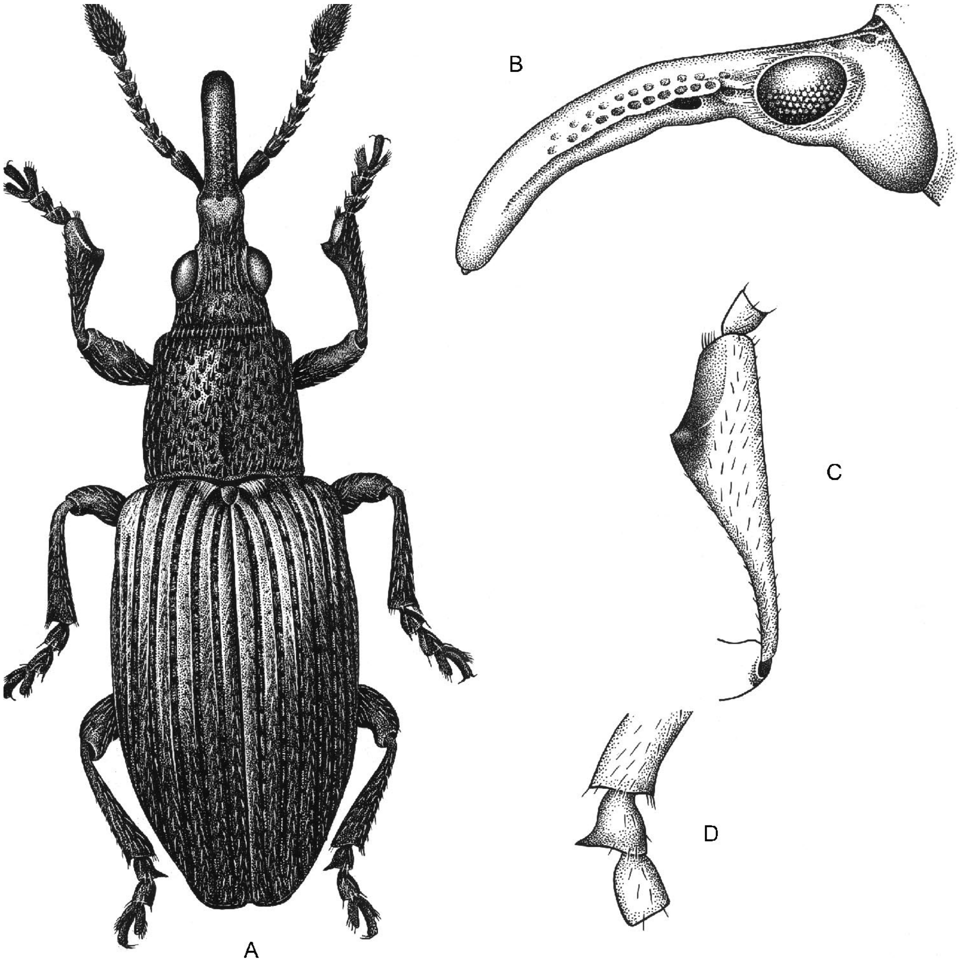

Fig. 5. *Ceratapion penetrans* (Germar). (**A**) ♂, dorsal view. (**B**) ♂ head, side view. (**C**) ♂ fore tibia. (**D**) First and second segment of ♂ hind tarsus.

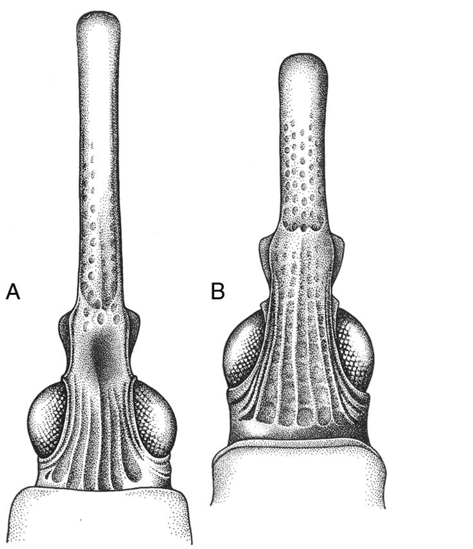

Fig. 6. *Ceratapion carduorum* (Kirby). (**A**) ♀ head, dorsal view. (**B**) ♂ head, dorsal view.

tibia with apical portion weakly incurved and armed with small denticle (=mucro); or lacking denticle and spatulate, strongly flattened and sharply dilated. first segment of male hind tarsus with small spine or large tooth near apex ventrally. - (2)

2a. Pronotum very densely and coarsely punctate; punctures elongate, partly merging to form short, undulate striae; intervals between punctures less than one-third width of puncture. Elytra deeply striate. Frons matte, densely striate; posterior part of frons and the vertex coarsely and rugosely punctate all way to anterior margin of pronotum. Rostrum weakly (in female) or moderately (in male) dilated at antennal base. Tarsi short, with claw-segment slightly protruding beyond hairy brushes of third segment. Body length, 1.69–3.12 mm.- - - - - - - - - - - -*C. onopordi* (Kirby) (Fig. 2).

2b. Pronotum shining, with sparse, medium-sized, shallow, round to weakly elongate punctures separated by about own width. Elytra finely striate. Frons flattened, smooth; frons and ver-

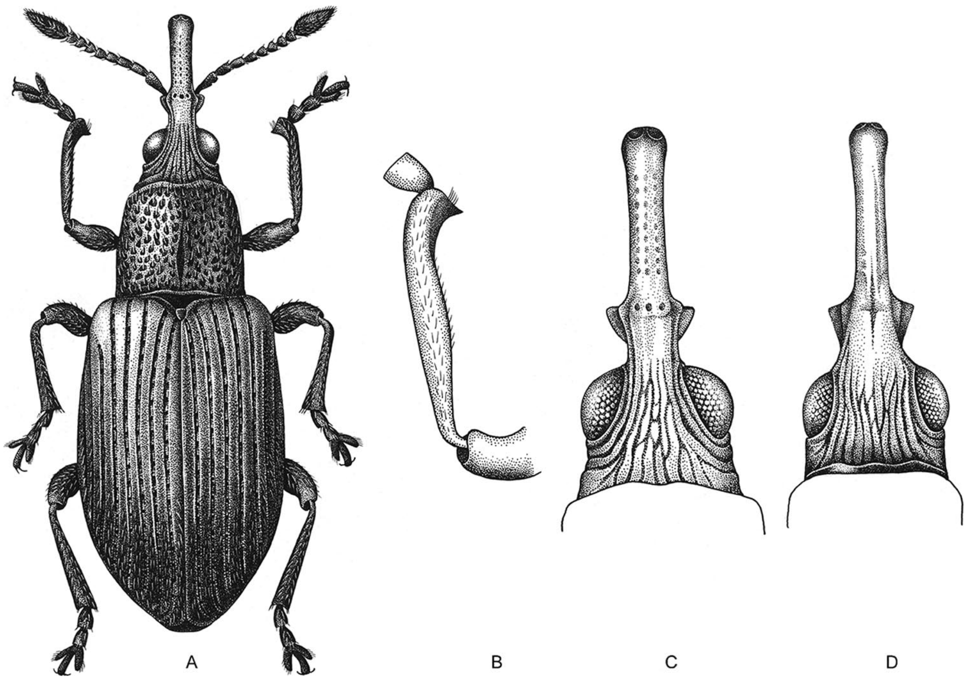

Fig. 7. *Ceratapion gibbirostre* (Gyllenhal). (A) ♂, dorsal view. (B) ♂ fore tibia. (C) ♂ head, dorsal view. (D) ♀ head, dorsal view.

tex with a few small elongate punctures. Rostrum strongly, but not acutely, dilated at antennal base; sparsely punctate and glossy distally. Tarsal claw-segment with apical one-thirds extending beyond lobes of third segment. Body length, 2.15–2.95 mm.- - - - - - - - - - - - - - - -*Ceratapion orientale* (Gerstaecker) (Fig. 3).

3a. Rostrum roundly dilated at antennal base. Apical third of male fore tibia strongly flattened and sharply dilated. First segment of male hind tarsus produced in large spine ventrally.- - - - - - - - - -(4)

3b. Rostrum abruptly dilated at antennal base. Male fore tibia weakly to moderately incurved and neither flattened nor dilated apically. First segment of male hind tarsus with only a small spine near apex ventrally.- - - - - - - - - - - - - - - - - - - -(5)

4a. Frons flattened or shallowly concave (Fig. 4A), finely striate; posterior part of frons, and the vertex often smooth medially. Temples of males, when viewed from above, weakly diverging posteriorly, occasionally subparallel (Fig. 4B). Pronotum dorsally flat, subcylindrical or slightly convex at sides (more noticeably in females). Intervals between punctures on pronotum flat and more or less shiny, especially at sides, where intervals usually subequal to width of puncture. Elytra shorter, with humeri somewhat more angular, and sides often more strongly rounded; apices more widely rounded, not cuneate; intervals of elytra more or less shiny, completely flat; striae fine and rather shallow. Legs more slender; second segment of fore tarsus noticeably longer than wide. Body length, 2.09–2.77 mm.- - - - - - - - - - - - - - - - - - *C. basicorne* (Illiger) (Fig. 4B).

4b. Frons weakly convex longitudinally (Fig. 5B), densely sulcate or striate throughout; vertex coarsely punctate. Temples of males more strongly diverging posteriorly (Fig. 5A). Pronotum slightly convex dorsally, somewhat more noticeably sloping to base; distinctly narrowing apically in both sexes; intervals between punctures on pronotum mostly convex, matte, coarsely microreticulate, at sides always less than width of puncture. Elytra longer, with humeri usually less angular and more or less beveled, and sides often more smoothly rounded; apices usually somewhat cuneate; intervals of elytra matte or scarcely shiny, more or less distinctly convex; striae deep, rather broad. Legs somewhat more robust (Fig. 5C); second segment of fore tarsus as long as, or scarcely longer than wide (Fig. 5D). Body length, 1.87–3.14 mm.- -*C. penetrans* (Germar) (Fig. 5A).

5a. Basal dilation of rostrum obtuse, rounded, with convex anterior margin; female rostrum longer, 1.37–1.58 times the length of pronotum (Fig. 6A and B). Male fore tibia straight or slightly incurved apically with minute mucro. Size larger, 2.3–3.3 mm.- - - - - - - - - - - -*C. carduorum* (Kirby).

5b. Basal dilation of rostrum acute-angled, with concave anterior margin; female rostrum shorter, 1.26–1.50 times the length of pronotum (Fig. 7C and D). Male fore tibia noticeably incurved apically, with stronger mucro (Fig. 7B). Size smaller, 2.04–2.95 mm.- -*C. gibbirostre* (Gyllenhal) (Fig. 7A).